AUSTRALIAN ENGINEERED FASTENERS AND ANCHORS COUNCIL

AEFAC Australian Engineered Fasteners and Anchors Council

Proposed Australian design standard and installer certification for safety-critical anchors to concrete

- David J Heath
- Ramil Crisolo

www.aefac.org.au

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DISCLAIMER

These seminar notes have been prepared for general information only and are not an exhaustive statement of all relevant information on the topic. This guidance must not be regarded as a substitute for technical advice provided by a suitably qualified engineer.

For further information contact David Heath: aefac@aefac.org.au

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OVERVIEW

Part 1

- Australian Engineered Fasteners and Anchors Council
- Safety-critical anchors
- Design methodology
- Case study
- Proposed AEFAC Standard

Part 2

- Post-installed fasteners
- Performance considerations
- AEFAC Installer Certification Program
- Additional resources
- Summary & acknowledgements

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AUSTRALIAN ENGINEERED FASTENERS AND ANCHORS COUNCIL

- ✓ United approach + improved safety + minimum standards
- ✓ Consistency in test methods and specification
- ✓ Education to industry

Formed in 2012 to stop anchor failures!

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AUSTRALIAN ENGINEERED FASTENERS AND ANCHORS COUNCIL

Guidelines for the specification of anchors
For Designers

Training & accreditation for installers of anchors
For Contractors

Minimum performance & standard specification
For Manufacturers

AEFAC

Guideline for field testing & certification of anchors
For Field Engineers

Research & Development
For anchor industry

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Founding Board Members

Swinburne University of Technology

Ancon Building Products

Hilti

ITW Construction Systems Pty Ltd

Ramset

reid

Hobson Engineering

Powers

Würth

Supporting Members

Simpson Strong-Tie

Allthread Industries

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AUSTRALIAN ENGINEERED FASTENERS AND ANCHORS COUNCIL

Board of Founding Members
Chair: Professor Emad Gad
Ancon, Hilti, Hobson, ITW Construction Systems, Powers, Würth & Swinburne University of Technology

National Technical Manager
David Heath

Training & Development Manager
Jessey Lee

Technical Committee
Chair: Neil Hollingshead (ITW)
Founding Members: *Joe Rametta (Hilti), Ramil Crisolo (Hobson), Hany Genidy(Ancon), Tarun Joshi (Powers), Emad Gad (Swinburne), Kamiran Abdouka (Würth)*
Supporting Members: *Brett King (Allthread Industries), Gilbert Balbuena (Simpson Strong-Tie)*
AEFAC: *David Heath, Jessey Lee*

General Members (future)
Other industry participants

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SAFETY-CRITICAL ANCHORS

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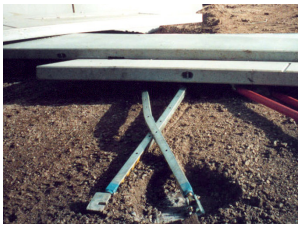
SAFETY-CRITICAL ANCHORS



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SAFETY-CRITICAL ANCHORS

Products
- Significant growth in use of anchor products
- New products entering the market

Governance
- Anchor industry largely relies on self-regulation
- How can you design to best practice?
- No Australian design or testing guidelines (except AS3850)

Conformity assessment
- Lack of conformity assessment culture in Australia
- What does the product conform to?

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SAFETY-CRITICAL ANCHORS

- *Safety-critical anchors - failure would risk human life and have potential for considerable economic consequences*

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SAFETY-CRITICAL ANCHORS

A "safe" anchoring system:

1. **PREQUALIFICATION** → Independent testing and assessment (via ETA/ICC) to demonstrate "fit for purpose"
2. **DESIGN** → Rigorous assessment to develop solution for a given application
3. **INSTALLATION** → Informed and competent installer having appropriate supervision

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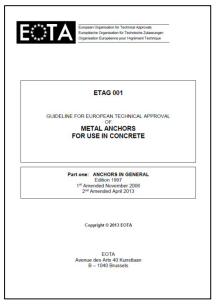
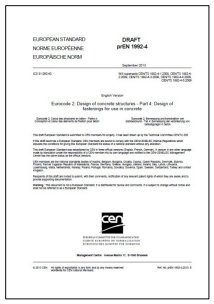
SAFETY-CRITICAL ANCHORS

European

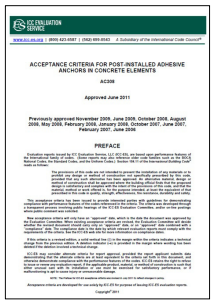


ETA
(prequalification)

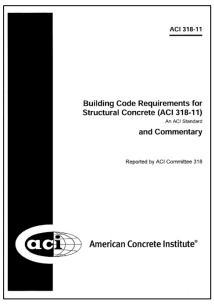


prEN 1992-4
(design)

United States



ICC ESR
(prequalification)



ACI 318
(design)

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DESIGN METHODOLOGY

$$N_{Rk,p} = N^0_{Rk,p}\left(\frac{A_{p,N}}{A^0_{p,N}}\right)\psi_{s,Np}\psi_{g,Np}\psi_{re,N}\psi_{ec,Np}$$

$$N^0_{Rk,p} = \tau_{Rk}\,\pi\, d\, h_{ef}\psi s_{us}$$

$$\psi_{g,Np} = \psi^0_{g,Np} - \left(\frac{s}{s_{cr,Np}}\right)^{0.5}\left(\psi^0_{g,Np} - 1\right) \geq 1$$

$$\psi^0_{g,Np} = \sqrt{n} - \left(\sqrt{n} - 1\right)\left(\frac{\tau_{Rk}}{\tau_{Rk,c}}\right)^{1.5} \geq 1$$

$$\tau_{Rk,c} = \frac{k_8}{\pi d}\sqrt{h_{ef} f'_c}$$

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DESIGN METHODOLOGY

AS3600 (2009)

Cl. 14.3 (d) Fixings

"The design strength of this anchorage shall be taken as ϕ times the ultimate strength, where ϕ = 0.6. In the case of shallow anchorages, cone-type failure in the concrete surrounding the fixing shall be investigated taking into account edge distance, spacing, the effect of reinforcement, if any, and concrete strength at time of loading."

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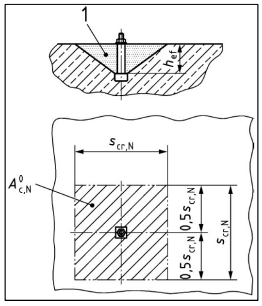
DESIGN METHODOLOGY

Concrete Capacity Method

- Developed in Europe
- Published in ETAG 001 (1997)
- ACI uses “CCD” (very similar)
- Accurate prediction of the suitability of a *specific* anchor to a *specific* application
- Only compatible with anchors that have been tested and assessed in accordance with strict guidelines



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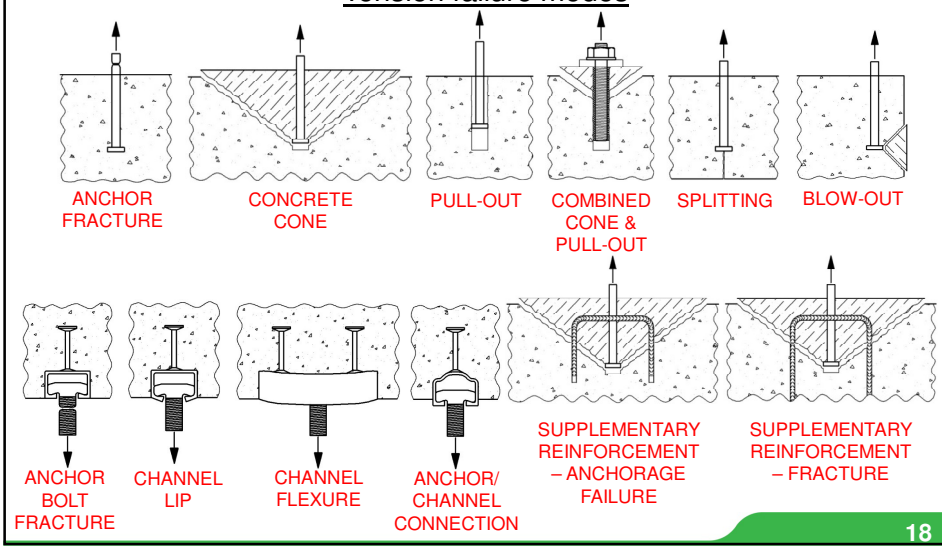
DESIGN METHODOLOGY

Tension failure modes



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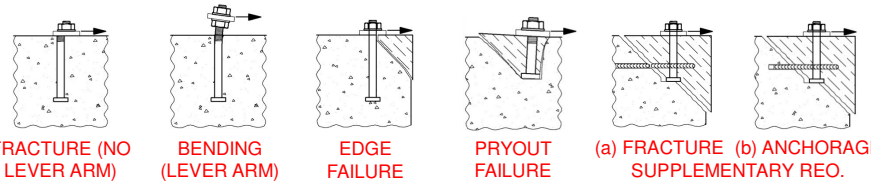
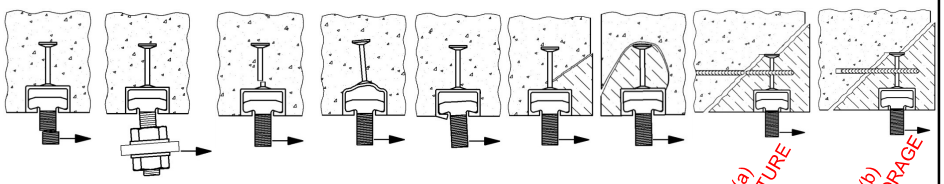
DESIGN METHODOLOGY

Shear failure modes



FRACTURE (NO LEVER ARM) | BENDING (LEVER ARM) | EDGE FAILURE | PRYOUT FAILURE | (a) FRACTURE (b) ANCHORAGE SUPPLEMENTARY REO.



FRACTURE (NO LEVER ARM) | BENDING (LEVER ARM) | ANCHOR FRACTURE | ANCHOR/ CHANNEL CONNECT. | LIP FLEXURE | EDGE FAILURE | PRYOUT FAILURE | (a) FRACTURE | (b) ANCHORAGE

SUPPLEMENTARY REO.

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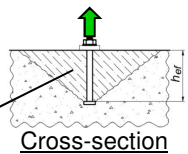
DESIGN METHODOLOGY

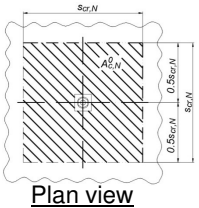
Example: Concrete cone failure mode (tension)

$$N_{Rk,c} = N^0_{Rk,c}\left(\frac{A_{c,N}}{A^0_{c,N}}\right)\psi_{s,N}\psi_{re,N}\psi_{ec,N}\psi_{M,N}$$

Inverted rectilinear pyramid



Cross-section



Plan view

$N^0_{Rk,c}$ = characteristic concrete cone strength (no spacing effects, edge effects, etc.

$= k_9\sqrt{f'_c}\,h_{ef}^{1.5}$

$\left(\frac{A_{c,N}}{A^0_{c,N}}\right)$ = adjustment for effects of fastener spacing and edge effects (can the full inverted rectilinear pyramid cone form?)

$\psi_{s,N}$ = factor accounting for disturbance of stresses in concrete due to an edge

$\psi_{re,N}$ = factor accounting for a dense layer of reinforcement in concrete

$\psi_{ec,N}$ = factor accounting for different tension loads on fasteners in a group subjected to eccentric loading

$\psi_{M,N}$ = factor accounting for the influence of a compression force between the fixture and concrete when a bending moment is present

NB: Still need to consider other potential modes of failure to determine decisive failure mode!

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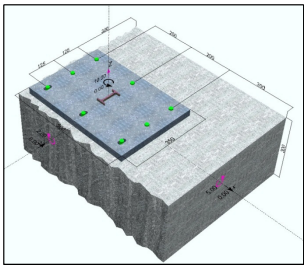
DESIGN METHODOLOGY

Software

- Freely available from reputable manufacturers
- Rapidly solve complex designs (minutes vs. hours/days!)
- Include prequalified products (i.e. ETA)
- Compatible with AEFAC Standard (with conversion)



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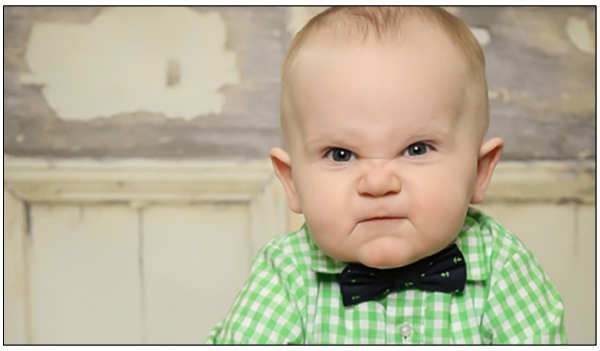
DESIGN METHODOLOGY



But I've been doing it *this way* for *years!*

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CASE STUDY

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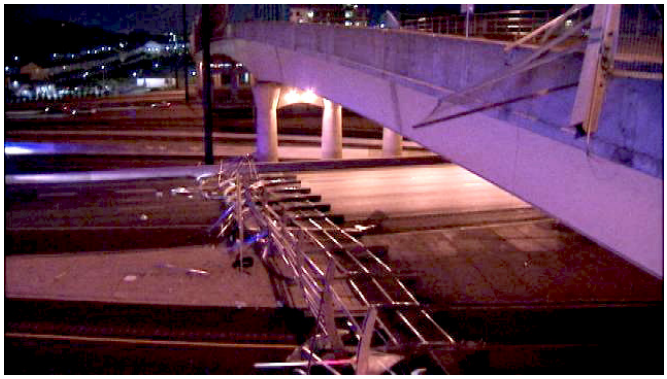
CASE STUDY

- 11.20pm, August 13, 2011, 190 feet (58 m) canopy-fence collapsed onto the 20 lane Interstate Highway 75/85



Source: www.wsbtv.com

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CASE STUDY

- Nobody was injured, no vehicles damaged
- Canopy-fence collapsed onto 20-lane Interstate Highway 75/85
- Investigation found:
  - Bridge opened seven years earlier (2004)
  - Anchors were subjected to **sustained load** that was substantially lower than (approx. ¼ of) the design service load
  - **Voids** 1 – 1.5 inches in length detected at rear of holes
  - **Wet epoxy** extracted from holes (7 years after installation)
  - Laboratory studies revealed **different material composition** in different areas and hardener-rich and resin-rich areas
  - Adhesive was susceptible to **creep**

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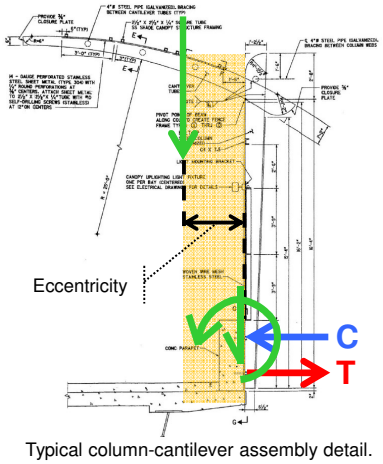
CASE STUDY

Bent anchor rod, some that is smooth – without thread

Epoxy removed from hole **seven years after installation**.



Typical column-cantilever assembly detail.

Source: 17th Street Bridge Canopy Failure Investigation, Report No. 2011.3732.0, WJE Associates Inc.

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PROPOSED AEFAC STANDARD

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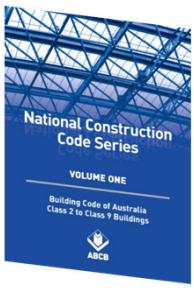
PROPOSED AEFAC STANDARD

Overview

- Based on European guidelines (prEN 1992-4)
- 'Adaptation' required: notation and terminology, referencing local standards, material properties, etc.
- Fundamental design procedure unchanged
- Compatible with products having ETAs
- Proposed referencing in Building Code of Australia
- Currently available for public comment (**www.aefac.org.au**)



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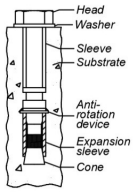
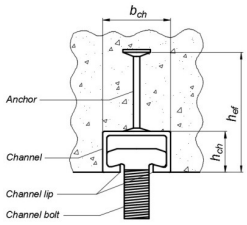
PROPOSED AEFAC STANDARD

Scope

- **Post-installed fasteners**
  - Mechanical anchors (expansion anchors, undercut anchors & concrete screws)
  - Chemical anchors (bonded anchors, bonded expansion anchors)



- **Cast-in fasteners**
  - Headed fasteners
  - Anchor channel



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PROPOSED AEFAC STANDARD

Development Committee

- Allthread Industries Pty Ltd
- Ancon Building Products
- Australian Building Codes Board
- Australian Engineered Fasteners and Anchors Council
- Australian Steel Institute
- Australian Window Association
- Commonwealth Scientific and Industrial Research Organisation (CSIRO)
- Concrete Institute of Australia
- Edith Cowan University
- Engineers Australia
- Hilti (Aust.)
- Housing Industry Association Ltd
- Hobson Engineering Company Pty Ltd
- ITW Construction Systems
- National Precast Concrete Association Australia
- Simpson Strong-Tie
- Stanley Black & Decker Australia Pty Ltd (Powers)
- Swinburne University of Technology
- Würth Australia Pty Ltd

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PROPOSED AEFAC STANDARD

Part 1 (overview)

- Materials and installation
- Determination of forces acting on fasteners
- Design for tensile loading
- Design for shear loading
- Design for combined tension & shear loading
- Design for serviceability
- Design for fatigue loading

Robust design methodology considering all modes of failure.

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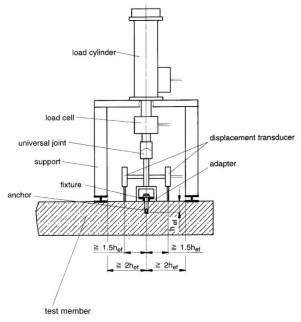
PROPOSED AEFAC STANDARD

Part 2 (overview)

- Test requirements for fasteners
- Assessment requirements for fasteners
- Manufacturing requirements
- Alternative path (products with an ETA)

Ensures fasteners are 'fit for purpose' and compatible with AEFAC Standard Part 1.



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PROPOSED AEFAC STANDARD

Why the proposed AEFAC Standard is important

- Consistency in terminology, notation and design data
- Greater certainty for specification of safety-critical fasteners
- Ability to easily distinguish quality fasteners
- Transparent testing and assessment of fasteners
- More flexible and efficient designs
- Seeking to align representation in the BCA/NCC with other types of safety-critical connections (e.g. welds, bolted connections, etc.)

Greater reliability, greater safety, reduced risk of failure!

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"The best anchor is only as good as its installation"

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POST-INSTALLED FASTENERS

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POST-INSTALLED FASTENERS

CATEGORIES

- **Fastening methods**
  - **Cast-in**
    - Channel
    - Headed inserts
    - Threaded sleeves/ferrules
    - L-, J-bolts
    - Bent reinforcement
  - **Post-installed**
    - **Drill & fix**
      - **Mechanical**
        - **Expansion anchors**
          - **Displacement controlled**
          - **Torque controlled**
        - **Undercut anchors**
      - **Bonded**
        - **Capsule**
          - Unsaturated polyester
          - Vinylester
          - Epoxy
        - **Injection**
          - Unsaturated polyester
          - Vinylester
          - Epoxy
          - Cementitious
    - **Direct installation**

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POST-INSTALLED FASTENERS

CHEMICAL ANCHORS: TYPES

Injectable

- Flexible to different sizes and variable embedment depths.

Capsule

- No wastage
- Faster to install

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POST-INSTALLED FASTENERS

CHEMICAL ANCHORS: COMPONENTS

Anchor rods

Internally threaded rods

Rebar

Special elements

Sieves

Injection Systems

Capsule Systems

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POST-INSTALLED FASTENERS

APPLICATIONS: STEEL TO CONCRETE CONNECTIONS

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POST-INSTALLED FASTENERS

APPLICATIONS: CONCRETE TO CONCRETE CONNECTIONS

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PERFORMANCE CONSIDERATIONS

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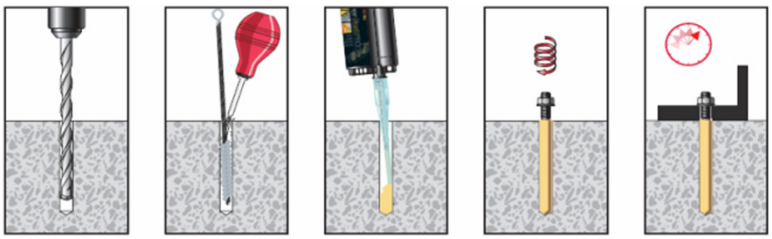
PERFORMANCE CONSIDERATIONS

INSTALLATION



1. Drill
2. Clean (blow, brush)
3. Inject
4. Insert anchor rod
5. Cure before installing fixture & correct torque

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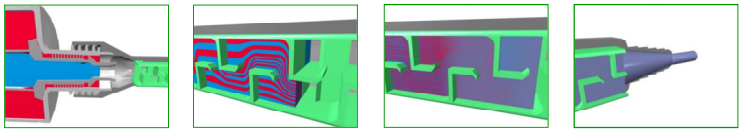
PERFORMANCE CONSIDERATIONS

INSTALLATION

Static mixer nozzle must not be shortened

Unmixed → Mixed



Waste product until even consistency achieved

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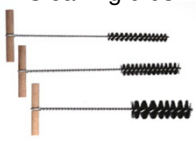
PERFORMANCE CONSIDERATIONS

INSTALLATION

ALL

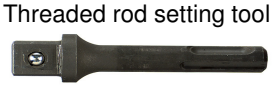
Cleaning brush



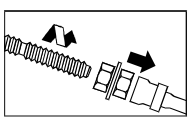
Blow-out pump

CAPSULE

Threaded rod setting tool



Socket



CARTRIDGE

Chemical Dispenser

Chemical Tube

Mixing Nozzle

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PERFORMANCE CONSIDERATIONS

INSTALLATION

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AEFAC INSTALLER CERTIFICATION PROGRAM

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INSTALLER ACCREDITATION PROGRAM

- Until now, performed on an ad-hoc basis – job dependent, product specific
- Reasonable errors acceptable, gross errors *dangerous*
- Combination of appropriate training and supervision critical
- Clear need for a program to provide:
  - Written and practical test
  - How to correctly drill
  - How to correctly prepare a hole
  - Understanding anchor systems
  - Understanding risks of errors

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INSTALLER ACCREDITATION PROGRAM

Element		Europe†	U.S.‡
Training	- theoretical	•	•
Training	- practical	•	•
	- vertical-down		•
	- overhead		•
Exam	- theoretical	•	•
	- practical	•	•
	- independent assessment	•	•
	- re-certification (written and practical)	2 – 3 years	5 years

† Performed on a Member State basis, currently only mandatory in Germany for post-installed rebar connections.
‡ ACI 318-14: "Installer certification and inspection requirements for horizontal and upwardly inclined adhesive anchors subjected to sustained tension loading shall be in accordance with 17.8.2.2 through 17.8.2.4." (Cl. 17.2.5)

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AEFAC INSTALLER CERTIFICATION PROGRAM

Written examination

↓

Practical examination
Part 1: Vertical down installation
Part 2: Overhead installation

↓

Certification awarded

↓

Recertification period
Initial: Three years
Additional: Every five years

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- **Written Examination**
  - ✓ 65 multiple choices &/or true false questions
  - ✓ 5 mandatory questions to answer CORRECTLY
  - ✓ 60 minutes
  - ✓ Closed book exam

- **Practical Examination (2 trials / day)**
  - ✓ Vertical down installation
    - Drill hole
    - Clean hole
    - Inject adhesive
    - Insert anchor
  - ✓ Overhead installation
    - Inject adhesive with piston plug

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- **Re-Examination**
  - ✓ If failed either written/practical exam, re-examination must be taken within 1 year after passing the other exam
  - ✓ If failed one of the 2 components of practical exam, e.g. overhead installation, only need to retake failed component
- **Recertification**
  - ✓ First recertification – 3 years
  - ✓ Subsequent – every 5 years

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- **Important note:**
  "*By completing certification, you have demonstrated that you understood the risks involved in poor installation practices*"
- **Failure to comply after certification awarded**
  - ✓ Certification status revoked
  - ✓ Potential legal implications!

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4TH FEBRUARY SOFT LAUNCH

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4TH FEBRUARY SOFT LAUNCH

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4TH FEBRUARY SOFT LAUNCH

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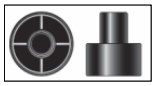
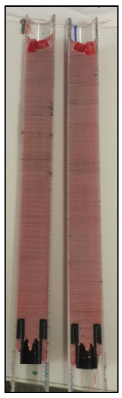

4TH FEBRUARY SOFT LAUNCH

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ADDITIONAL RESOURCES

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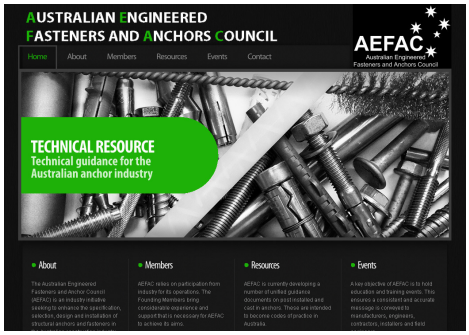
ADDITIONAL RESOURCES

WWW.AEFAC.ORG.AU

- Overview of AEFAC
- AEFAC members
- Education events
- Technical Notes
- Sample Specifications
- Proposed AEFAC Standard
- Links to resources



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ADDITIONAL RESOURCES

- **Australian Engineered Fasteners and Anchors Council**
  www.aefac.org.au
- **European Organisation for Technical Approvals (EOTA)**
  - AEFAC endorsed **www.eota.eu**
- European Technical Approval Guideline 001, Parts 1 – 5, Annex A & B, **www.eota.eu**
- prEN 1992-4:2013 Eurocode 2: Design of concrete structures – Part 4: Design of fastenings for use in concrete
- BS 8539:2012 "Code of practice for the selection and installation of post-installed anchors in concrete and masonry"
- Construction Fixings Association (UK): **www.fixingscfa.co.uk**
  - Comprehensive guidance on best-practice for selection and application
- Australian Technical Infrastructure Committee – endorses European design
  - ATIC SP38 & SP39 (see **www.apcc.gov.au**)
- Standing Committee on Structural Safety (SCOSS) **www.structural-safety.org**

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SUMMARY & ACKNOWLEDGEMENTS

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SUMMARY & ACKNOWLEDGEMENTS

- Anchor industry is ***safety-critical***.
- Anchor failures should not happen – they do!
- AEFAC has created a body of knowledge and expertise to introduce governance to the Australian anchor industry
- The proposed AEFAC Standard seeks to provide a consistent and robust approach to anchor design based on best practice
- The AEFAC Installer Certification Program has been developed to equip installers with the skill to ensure that anchors are installed as intended
- Collectively, these measures introduced by AEFAC are lifting quality and safety standards in the Australian construction industry.

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SUMMARY & ACKNOWLEDGEMENTS

Founding Board Members

SWINBURNE UNIVERSITY OF TECHNOLOGY

Ancon BUILDING PRODUCTS

HILTI

ITW Construction Systems Pty Ltd

Ramset™ reid

HOBSON ENGINEERING

Powers

WÜRTH

Supporting Members

SIMPSON Strong-Tie

ALLTHREAD INDUSTRIES

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